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Luminary Memo No. 217

TO: Distribution
FROM: R. A. Larson
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SUBJECT: Luminary 1E Program Notes

The attached set of program notes is a first cut for Luminary 1E. I have taken the liberty to update the notes for Apollo 14 as published by NASA/MSD FSD in memorandum 70-FS55-209 (Luminary portion). Notes indicated by an asterisk in the margin are new notes for Luminary 1E.

Program and Operational Notes Applicable to the J1 Mission
for the LUMINARY Program

2.1 Nouns, Verbs, and Displays

2.1.1 The nouns that can be called at any time with valid data are: 1, 2, 3, 8, 9, 10, 15, 20, 21, 27, 36, 38, 47, 65, 72, R1 of 45, R2 of 46 and R2 of 66.

2.1.2 N42 values of ha and hp (in P30) are preburn predictions and will vary slightly from N44 values (post-burn estimates). N42 assumes the ΔV will be burned impulsively. The larger the ΔV , the greater the error in N42. Recognition: Difference in displays.

*2.1.3 When loading decimal data into the LGC, the ENTER sometimes changes the last digit of the loaded value since PINBALL roundoff in decimal/octal/decimal conversions occur when data is keyed in (decimal to octal) and entered and redisplayed (octal to decimal). Data shown on the DSKY can be displayed as modulo the maximum value allowed or can be data from a previous calculation that was stored into the cells picked up for display. The crew is encouraged to always write over data with the desired information.

*2.1.4 There are seven priority displays in LUMINARY which ignore any response for 2 seconds:

V06N49 in R22
V50N18 in P20 or P25
V50N72 in P20
V05N09 in P20 (Alarm codes 501, 503, 514, 525)
V06N05 in P20, P22
V16N80 in P20
V05N09 in P22 (Alarm codes 503, 514, 525, 530)
The PRIO DISP LT (N49) is turned on by all priority displays.

*2.1.5 The following functions are not restart protected.

- a) Astronaut initiated verb/nouns
Recovery: Reselect verb/noun
- b) Extended verbs
Recovery: Reselect extended verb
- c) Automatic attitude maneuvers
Recovery: PRO to V50N18 that returns to DSKY after restart. If V49 or V89 maneuver, reselect extended verb.

*2.1.7 On a monitor display when the DSKY is "frozen" by pressing a DSKY key, the data that is displayed may be incorrect. This is because the pressing of the DSKY key may have occurred prior to the final computation of the display parameter resulting in the display of a partially computed quantity. Recovery: Release the DSKY to allow the computations to be completed.

2.2 Selection of New Programs and Extended Verbs

2.2.1 The following program sequences may cause problems:

P3X-P47-P40, P41, or P42 - The P3X computations may be overwritten. Recovery: Repeat P3X and then P40, P41, or P42.

2.2.2 If V37 is attempted within approximately 15 seconds of a fresh start or ISS turn on, a PIPA FAIL will go undetected. Recognition: None by the crew, ground support will see IMODES bit set. Recovery: Select P00. Then reset IMODES 30 bit 5 via V25N07E, 1277E, 20E, E.

2.2.3 During periods of high computer activity, the selection of certain extended verbs (notably V82, V83, V85, V90) or other DSKY activity may result in program alarms 31201 or 31202 and extended verb activity is lost. Recovery: Reselect extended verb.

2.2.4 If an extended verb has been selected during a mission program, with normal displays, the extended verb logic initially blanks the DSKY. Any response (PRO, ENTER, V32E, V33E, V34E) during the time the DSKY is blank would do one of the following things: a) respond to a normal mission program display underneath the extended verb; b) respond to the first display in the extended verb which could be initiated simultaneously with your response. In general, do not key a response to either a blank DSKY or a non-flashing display.

2.2.5 If RR is in Mode II, do not select a mission program via V37 after selecting P20 until the first R60 display in P20 (V50N18 priority display) (SDN-48). Recognition: RR may lock on in Mode II before the V50N18 if the +X axis is along the LOS. Recovery: Attitude maneuver (V50N18) will break lock, position the +Z axis along LOS, and RR will be designated to Mode I.

*2.2.6 If P20 is selected prior to completion of P66 there is one problem that can occur:

a) If P20 is selected in the update mode the W-matrix initialization will destroy the E-memory descent targets.

2.2.7 Depending upon initial gimbal angles, the VECPOINT routine may result in large desired rotations about the pointing vector when the pointing vector must be rotated through about 180° (an example of this would be in P40, P41, or P42). If the +X axis were about 180° away from the desired thrust vector, the V50N18 may display a large change in yaw desired. Recovery: If the computed attitude is desired then simply proceed with the maneuver. If it is not, then manually maneuver in pitch and have the solution recomputed after some 20-to-30 degrees by keying PRO on V50N18.

2.2.8 Any program can be terminated:

a) Via V34E at any flashing display except the flashing N64 in P64, N60 in P66, N49 of P20 and P22, the flashing N88 in P51, P52, or P57, or V50N25 in P06 (V34E response to an extended verb display will terminate the extended verb and not the program running underneath).

b) Via V37EXXE at any flashing or non-flashing or non-flashing display except with XX not equal to zero for V06N16 in R47 and V50N25 in P06.

*2.2.9 When a new program selection is made via V37, the key release light will remain on during R00 and will not go off until the new program is started. No further keyboard activity should be attempted until the key release light goes off and the new mode lights are displayed.

*2.2.10 Blank major mode lights indicate that a fresh start has been performed except in two cases. A restart (hardware or software) with no restart phases active (no programs to be restarted) will result in a flashing V37 with major mode lights blank.

* 2.2.14 A RR turn on immediately before selecting P20 or P22 may cause erratic behavior. Avoidance: wait 10 seconds after RR LGC mode before selecting P20/P22. Recovery: Cycle RR MODE Switch from LGC-to-SLEW-to LGC.

2.3 Ground Updates and Pad Loads

2.3.1 The PROCEED key is now ignored whenever a load verb is in the verb lights. Therefore, when it is desired to answer a flashing load verb with a PROCEED (as in P27) V33E should be keyed in rather than the PROCEED key.

2.3.2 The program will ignore any attempt to load channel 7 via the DSKY. It will not even alarm. Channel 7 is the superbank indicator and is under exclusive program control.

* 2.3.5 The maximum unit vector that N88 will accept is .99996. Any value greater than that will result in an operator error. An MIT/SDL investigation of the planets and the 1078 stars in the American Ephemeris and Nautical Almanac indicates that no celestial bodies will present a problem.

2.4 Navigation and W-matrix

2.4.1 A V96E can cause the W-matrix to be out of phase with the state vectors if it is performed: 1) during P20 mark processing, but only if the CSM state is being updated (V81); or 2) during AVETOMID, i.e., after responding to the FLV37 when leaving a program where Average-G was on and before the program lights change. Recovery: For 1) none needed; 2) V93E.

2.4.2 If a V37EXXE, abort button, or abort stage button is used or if a software restart occurs when the RR or LR is being read, a 520 alarm may occur. The data that was being read is not used. Recovery: ERROR RESET and continue.

2.4.3 If V56E or V34E on a P20 display (excepting N49) is keyed to terminate P20 during a computation in P32, P33, P34, P35, P72, P73, P74, or P75, these computations will be restarted from the beginning.

2.4.4 If a recycle (V32E) response to a V06N49 display is used to reject an excessive state vector update from a trunnion angle measurement (R3 of N49 = 4), the mark counter will be incremented. Avoidance: Key terminate (V34E) in response to a N49 display from the trunnion angle measurement.

2.4.5 Range rate display in V83 may degrade considerably at ranges less than 0.3 to 0.5 n.m. depending on navigation accuracy.

* 2.4.8 If Range to CSM is $\dot{> 400\text{n.mi.}}$ and \dot{R} is negative when P22 is selected, V37 will not flash when Range to CSM $> 400\text{n.mi.}$ and R is positive (after CSM passes over). Avoidance: select P22 when Range $< 400\text{n.mi.}$ Recovery: V37E00E when NO TRACK light comes on. It is recommended that the recovery be used rather than trying to avoid the problem. Anomaly L-1E-01.

2.5 Rendezvous and Targeting

2.5.1 Lambert computations should not be used within 3 degrees of a target vector.

2.5.2 The \underline{V}_g or $\underline{\Delta V}$ displays in body axes, N85 or N83, are based on reading the accelerometers every 2 seconds. The displays, however, are asynchronous 1-second monitors. The result is a $1/2 - 1\ 1/2$ -second delay between application of ΔV and the visible result.

2.5.3 P20 rendezvous navigation provides a priority display (V06N49) of ΔR and ΔV when the state vector update exceeds the padloaded erasable values RMAX and VMAX. Currently there are two problems: 1) If the display is desired before every incorporation, any negative value must be set into RMAX, not zeroes; 2) ΔR is displayed as zero if $\Delta R < 256$ meters for earth or < 64 meters for moon; ΔV is computed as zero if $\Delta V < 0.006$ meters/second for earth or < 0.0015 meters/second for moon. Avoidance procedure: If it is desired to observe V06N49 for each mark, then RMAX should be loaded as any negative number. Recovery procedure: None.

* 2.5.6 Do not key a PRO response to the V16N80 display in R24, automatic search routine, in P20 unless R1 = 11111, indicating RR lockon achieved. Recovery: Reselect P20 and redo R24. A PRO response with R1 = 00000 results in the program getting hung up in an RR designate loop which will never terminate. Anomaly L-1E-09.

* 2.5.7 P77 displays ΔV via N81. P76 displays ΔV via N84. To recall the loaded ΔV N84 should be used by both programs. The N81 values in P77 are stored in N84 after the PRO on N81.

2.6 Optics, IMU, and Radars

2.6.1 If the mode control switch is in AUTO or ATT HOLD with rate command/att hold selected (V77E) during R55 (gyro torquing routine) or during V42 or during execution of the gyro pulse torquing option of P52, the DAP will maneuver the vehicle to follow the platform as it moves.

2.6.2 If P20 is in progress, a hardware restart will remove TRACK ENABLE and force the program back to the beginning of the designate and attitude maneuver. Recovery: Self recovery.

* 2.6.4 If a restart (hardware or software except V37E XXE) occurs during a CDU zero while the DAP is disabled, the DAP will remain disabled. Avoidance: None. Recovery: Repeat the V40N20.

* *2.6.7 With a failed on ROD switch MARK REJECT functions are inhibited.

2.7 Guidance and Control, Boost and Entry

2.7.1 Do not select P40 or P42 if $VG \leq \Delta V_m$ (i.e., ullage DELTA V should not exceed the total velocity-to-be-gained). The engine will be turned on for 0.01 second; may cause engine freeze-up and may be dangerous to crew safety. Recognition: R2 of N40 is less than 45000/weight prior to TIG-30. Recovery: Confer with ground.

2.7.2 In order to avoid the excitation of the CSM-docked bending mode and possible damage to the docking tunnel, rapid pulsing of the ACA should be avoided in the ATT HOLD/rate command mode. Recognition: Perceiving a surprising increase in RCS jet activity and seeing a sinusoidal motion on the FDAI error needles (between 2 and 4 cps).

2.7.3 During thrusting programs when V99 or V97 is flashing, V06 may occasionally appear for one flash. There is no recovery procedure required.

2.7.4 A KALCMANU maneuver rate in excess of $0.5^\circ/\text{sec}$ should not be used in the CSM-docked configuration.

2.7.5 For a certain range of fuel loading in the CSM-docked configuration the LM +X thrusting jets produce a negative torque due to impingement on the RCS jet plume deflectors. Therefore a disabled or failed off -X thrusting jet can cause instability in the CSM-docked control during coasting flight. Avoidance: Disable all deflected (+X thrusting) jets when the c.g. is above STA 364.

2.7.6 Do not load a zero or negative number in R1 or R2 of N48 (DPS pitch or Roll trim) (SDN-124). Recognition: 21204 alarm with V37 flash. Recovery: Recall present program and R03.

2.7.7 The TGO display in N40 is discontinuous immediately after ignition. The ΔV measured becomes fairly constant and the computation settles out in four-to-five seconds.

*2.7.8 The crew should disable jet failures detected (or suspected) during the low-throttle period of P63 or P40 as quickly as possible. The attitude should then be carefully monitored at throttle-up. If the excursion is unacceptably large, the engine must be throttled down or stopped.

2.7.11 During P66 "manual mode" the desired attitude to arrest the horizontal velocities is displayed on the FDAI attitude error needles. A limit (presently 20°) has been imposed on the allowable attitude from the vertical when in P66 "auto". If the horizontal velocities are large enough to cause the desired attitude to be greater than this limit, the FDAI attitude error needles will display the desired attitude module 20° .

- * 2.7.12 If P70 or P71 are attempted after touchdown but liftoff is not allowed, the subsequent P12 to launch into orbit will be targetted for and guided with Variable Insertion Targeting equations. The orbit will be a safe orbit, but the phasing with the CSM will be that which was set up earlier by the P70 or P71 attempt. Recognition: Insertion velocity in NOUN 76 display. Avoidance: reset flag set in P70 or P71

V25N07E
105E
10000E
E

Recovery: None necessary. Anomaly L-1D-24.

- * 2.7.13 Due to the thrust direction during ullage not passing through the center of gravity the LM will move toward the deadband, possibly exceeding it, and the attitude at ignition is wrong. A restart during ullage will cause the desired CDU's to be equal to the actual CDU's and the center of the deadband is redefined. So, one Restart during ullage may double the attitude error at ignition.
- * 2.7.14 If the discrete from the GUID CONT switch (PGNCS or AGS) fails such that the indicated mode is AGS control even though PGNCS is still in control, attitude maneuvers in P40, 41, 42, P63, V49, V89, P20, P25, P52, P99 must be performed manually. NOUN 18 ball angles are computed in each of the above instance.
- * 2.7.15 With the DAP deadband of 0.3° and a phase plane logic containing a "flat" of 0.8° , the DAP does nothing to correct an attitude error of up to 1.1° providing it computes that the yaw rate error, however slight, is such as to diminish the yaw error. There are several ways, too elaborate to describe here, in which the yaw error can be produced. The resolution of FINDCDUW's rate commands is much finer than the resolution of the angle commands, which in many cases causes the DAP to erroneously compute that the yaw rate error is such as to diminish the yaw error; consequently the DAP does nothing and the error persists. The flat was designed to facilitate transfer of U and V axes control to the trim gimbal. The trim gimbal does nothing for yaw, but the flat was retained in the yaw channel to preserve similarity with the other channels, the additional 0.8° yaw error not seeming objectionable. With azimuth-redesignation granularity to be 1° , the 1.1° yaw error may be objectionable, and perhaps the flat should be eliminated in yaw.
- * 2.7.16 Exiting P63, P40 or P42 with a V37E approximately 50 microseconds before ullage on will result in ullage coming on and not being terminated, with Average-G integration not running. The mission effect is a degraded state vector since ullage is on and average-G is not on. Avoidance: Key V37E prior to TIG -10 seconds. Recovery: If avoidance not possible, key V37E after ullage comes on.

- * 2.7.17 The delta velocity (DV) measured every two seconds during powered flight may be in error up to 20 fps at the beginning of an Ascent (P12), and remains throughout the Ascent. There is no mission effect since the DV is only on the downlink and is not used for guidance or navigation.
- * 2.7.18 The DAP configuration code that occupies the first register of N46 can only be displayed or changed effectively in Routine 3. However, the in-bit override that occupies the second register of N46 can be displayed and changed either in Routine 3 or without it.
- * 2.7.19 If the PGNCS/AGS indication (channel 30/bit 10) fails in either state and the control is, at some time, actually switched from AGS to PGNCS the switch will not be visible to the DAP and it will not re-initialize its estimates of angular rate and (in powered flight) angular acceleration, which become seriously distorted when AGS is in control. There is likely to be a violent transient in the attitude under these conditions unless the DAP is forced to re-initialize by means of a restart (V69) or a (momentary) switch to the OFF mode. Result of PCR 1111, which calls for the DAP to attempt control even with an AGS indication.

LUMINARY 1D NOTES DELETED

*2.1.5 The following functions are not restart protected.

- d) Furthermore, if a restart occurs during the automatic attitude maneuver in P63, program control is transferred back to the V50N25 display. (Please perform IMU fine alignment.) Recovery: Key in ENTER to the V50N25 and then PRO to the V50N18 that will return to the DSKY.

*2.2.6 If P20 is selected prior to completion of P66 there are two problems that can occur:

b) RM of P20 shares E-memory location with padload "LRWH1." Therefore, if P20 is selected in the no-update mode and is allowed to proceed past the V50N72 RM will destroy the LRWH1 padload (L-1D-08). Recovery: Reload LRWH1 via V21N01E3756E XXXXE.

*2.2.11 The following extended verb routines should not be requested if P20 or P22 is running and the range to the CSM is greater than 400 n.m. (L-1D-05).

R04	V63	LR/RR self-test
R05	V64	S--band antenna
R30	V82	Apogee/Perigee display
R31	V83	Range/Range Rate display
R36	V90	Rendezvous out-of-plane display
R47	V47	AGS initialization
	V67	W-matrix monitor
	V85	Mode II RR position display

Recognition: Erroneous displays from extended verbs. Bad AGS update if V47 requested.

*2.2.12 A restart during AGS initialization (V47E) may leave the NODOFLAG set so that major mode change to any program except P00 is not allowed. Recovery: Reselect V47E or clear flag via V25N07E 76E1EE.

2.2.13 Use of V30 or V31 (which uses N26 as transfer address) in programs that share N26 erasables may cause indeterminate transfer (LNY-31). Avoidance: Use V30 or V31 only in P00. Recognition: Unexpected DSKY displays or activity. Recovery: Standard recovery (documented in crew checklist).

*2.3.3 There is an inherent error in the LGC computed unit vectors for the Sun and Moon. This error is further degraded in the Apollo 14 LUMINARY program because one of the constants used in the computation of the Moon position was inadvertently misscaled by a factor of 2. The inherent Moon position error is a maximum of 1.1 degrees. The maximum as computed in the Apollo 14 program is 3.3 degrees (L-1D-11). Avoidance: If the Sun, Moon, Earth options are to be used in the LGC for an alignment, the ground should uplink the unit vectors.

2.3.4 In P40 if TGO is computed to be less than 6 seconds, NO THROTTLE FLG is not set. Therefore, the engine is commanded to FTP at TIG+ZOOMTIME (L-1D-14). No mission effect.

*2.4.6 The flashing V37 which terminates P22 when the range is greater than 400 n.m. and the range rate is positive may not occur (L-1D-17). Recognition: After RR tracks CSM into mode limits and no track light goes on, the V37 flash does not appear. N54 is computed though. Recovery: Select desired program when 530 alarm appears in P22.

*2.4.7 In P22, if the R21 routine (RR designate) drives the antenna close to the RR Mode II limits as the CSM is moving away from the landing site, the RR antenna may oscillate between the mode limits and the mode center several times (L-1D-18). Recognition: Oscillation of antenna trunnion and shaft angles varying between mode limits and mode center. Avoidance: Select P22 while CSM is approaching landing site and not yet within RR mode limits.

*2.5.4 P25 cannot be used to control vehicle attitude if range to CSM is greater than 566 n.m. (L-1D-04). Recognition: After selection of P25 no attitude changes occur; possible alarm light (code 526).

*2.5.5 A P00D00 abort while P20 or P25 is running in the background will kill the P20 or P25 and prevent its reestablishment unless RNDVZFLG (P20) or P25FLAG (P25) is cleared (L-1D-15). Recovery: Select P00 at the P00D00 V37 request.

*2.6.5 If the IMU is caged or put into coarse align during pulse torquing, repeated core set overflow alarms (31202 BAILOUT alarms) may occur (L-1D-02). There is a remote chance that this could happen during AVERAGE-G if the platform goes into gimbal lock. Avoidance: Do not coarse align during AVERAGE-G. Recovery: V21N01E 1477E 40000E.

*2.6.6 Selection of V41N72 while an RR reposition or remode is in progress results in incorrect operation of the V41N72. Also, keying in V44 while a reposition is in progress will cause erroneous operation of a subsequent V41N72 (L-1D-12). Avoidance: Do not key V41N72 while a reposition or remode is in progress or V44 while a reposition is in progress. Recovery: Cycle RR mode select switch from LGC to SLEW wait at least 1 second and back to LGC.

*2.7.9 There are a number of windows during which a change in major mode would wipe out a waiting 1/ACCS job leaving the DAP with improper data (L-1D-10). Avoidance: The following should be avoided: 1) exits from powered flight programs after the preburn attitude is calculated that do not go through the final displays of that program, 2) termination of P20 or P25 during the execution of R23 or R60, 3) termination of R03 by a change in major mode, 4) change in major mode within a second of operating an RCS isolation valve. Recovery: V48E, PRO, V34E.

*2.7.10 If the PGNCS mode control switch is moved from ATT HOLD to AUTO just after a pitch or roll rate command is terminated and if X-axis override is inhibited, then when the X-axis override inhibit is removed the DAP will start to yaw back to the attitude at the time that the switch was moved (L-1D-07). Avoidance: Do not switch from ATT HOLD to AUTO after a pitch or roll rate command during the parts of ascent and descent that inhibit X-axis override. Recovery: Move the ACA rapidly out of detent and back in the yaw axis when the unexpected maneuver occurs in order to establish a new yaw reference attitude.